

EPA Questions # 4 and #5

Description of Geotechnical Survey Sampling Technologies & Discussion of Types and Relative Frequency of Drilling Fluid Additions.¹

Introduction

There are many various industry technologies available to accomplish field data acquisition for geotechnical surveys at a given site. The data required are described under the Code of Federal Regulations (CFRs) 30 CFR §§250.906 and 250.907 for design and installation of offshore facilities for oil and gas production in the United States, including the arctic North Slope of Alaska. Not all available technologies are feasible for use given the remoteness of the Arctic. Shell Exploration and Production Company – Alaska Venture (Shell) researched numerous technologies and based on operational considerations presents the most appropriate in the following paragraphs for use offshore, nearshore, and onshore. The categories are presented as offshore technologies, nearshore technologies, and, shore-crossing and land-based (onshore) technologies. The delineating water depth between offshore and nearshore is taken as approximately 25 meters (m). It is assumed that offshore and nearshore geotechnical surveys using its associated technologies may occur during open-water seasons in any given year. Shore-crossing surveys and its technologies are assumed to be operated from landfast ice during January-March of any given year, while onshore surveys and technologies are assumed to be operated from a Rolligon on snow pack during the winter months when ice roads can be constructed.

Offshore Geotechnical Technologies

The following paragraphs describe the most favorable field data acquisition technologies Shell has identified for accomplishing offshore geotechnical surveys (>25m water depth) in the Chukchi and Beaufort Seas off Alaska. Information on seabed-based geotechnical technologies that may be used in the future is also provided

Conventional Wet-Rotary Techniques. Wet-rotary sampling techniques are the methods most favored by Shell to accomplish geotechnical surveys offshore. These proven and successful methods have been employed in offshore environments since the 1940s. Conventional techniques are generally performed from a variety of vessel types with industry standard drill pipe and a top-drive drilling rig, specialty drill bits with a single center open port, specialty sampling/coring/*in situ* gear and a seabed frame/guide base used as a reaction mass. These activities are generally performed from the deck of a vessel positioned on location by either Dynamic Positioning (DP) utilizing satellite technology, or with older vessels a 4-point anchor spread.

¹ What is provided herein is believed to be a good representation of the subject matter at the current time, but processes, procedures and technologies may in the future be subject to some alteration owing to information/experiences obtained in the field and/or Shell's future developmental plans.

To accomplish these activities, the general procedures are:

- The vessel is positioned over a borehole location and the DP system is engaged. The DP system is allowed to settle in for about 30 minutes to one hour while the deck crew rigs up the geotechnical survey apparatus and sampling equipment.
- Once the DP positioning is approved, the conventional API drill pipes and Bottom Hole Assembly (BHA-latching system and drill bit) are lowered from the deck of the vessel to just above the seafloor using the drill rig top drive.
- A scanning sonar unit is then deployed through the drill pipe and latches in the BHA. This sonar unit is used to develop an electronic rendering of the seabed immediately below the drill string in order to assess if there are obstructions to lowering the SeaBed Frame (SBF) to the seafloor.
- If a 4-point moored vessel is used for the geotech activities, then each planned anchor location is assessed with the scanning sonar as described above.
- Once the site is cleared, the SBF is lowered to the seafloor over the drill pipe with a two-part heavy lift winch. A centralizer apparatus is used above the SBF to keep the winch cables from fouling on the drill pipe.
- With the SBF firmly supported on the seabed, sampling activities may commence. The drill pipe is lowered through the clamps located on the SBF and positioned just above the mudline. A sampling tool with a core tube attached (there are many various sampling/coring tools used depending on the soil type expected to be encountered) is lowered through the drill pipe with a wireline unit and latches firmly in the BHA. Once latched in the BHA the sampling tube extends approximately 1 m beyond the drill bit. Once latched, the drill pipe is then lowered with the top drive unit and the sampling tube is mechanically “pushed” into soil by the weight of the drill pipe. The drill pipe is then pulled out of the soil to just above the sampling depth with the drill pipe and top drive.
- The sampling tool and tube is then retrieved to the deck of the vessel using an overshot and the wireline unit. Once the sample is recovered to the deck, the borehole is advanced to the next sampling depth using wet rotary techniques. This process is repeated until the borehole is advanced to the planned final depth. Shell will not advance geotechnical surveys boreholes deeper than 499 feet (ft) in compliance with Bureau of Ocean Energy Management (BOEM) regulations.

There are many combinations of sampling tools and core barrels that can be used to accomplish the borehole objectives. Each tool is designed for specific soil types and each tool is operated in different ways. All tools are deployed and retrieved via a wireline through the drill pipe as described above. Sometimes, If the planned geotechnical survey program calls for it, an *in situ* testing tool called a Piezo Cone Penetration Testing (PCPT) sounding device can be lowered to the BHA on an electric cable and activated to electronically measure pore pressure, cone tip resistance, side friction, and optionally seismic response of the *in situ* soils up to 3 meters ahead of the drill bit. Since the soil response is measured with electronic sensors, no sample is recovered to the deck at the end of the sounding.

Use of Drilling Fluids. Wet-rotary techniques advance a soil boring as an “open-hole” using only the BHA and drill string to drill out the formation between sampling and *in situ* testing intervals. This involves the use of drilling fluids to (1) lubricate the drill string, preventing stuck pipe, and (2) “lift” or flush the formation cuttings out of the borehole. The mud pumps are adjusted to provide approximately 60 to 120 fps of drilling fluid traveling up the annulus of the

borehole from the drill bit to the mudline (recommended range to flush most cuttings from a typical borehole). The drilling fluid and formation cuttings are expelled from the borehole annulus at the mudline and not recovered to the deck utilizing open-hole techniques. For any typical borehole we attempt to use only seawater as the drilling fluid to as deep as possible before the encountered stratigraphy necessitates the use of additives and we start mixing actual mud additives in the drilling fluid.

Typically the first sign of the need to add mud additives to complete a borehole is when unconsolidated sands are encountered in the borehole. These sands tend to “flow” into the borehole and may cause the pipe to stick. Also, sand may enter the BHA and cause the sampling/coring tool to become stuck. Both are situations that could lead to damaged equipment or worse, lost drill pipe or sampling equipment downhole. The first step to alleviate these flowing sands is to mix a viscosifier (gelling agent) into the drill fluid pit. The viscosifiers we typically use are either naturally occurring Attapulgite Clay based products, Guar gum, or a water soluble polymer based product. These viscosifiers tend to create a “wall pack” in the boring preventing the unconsolidated sand from flowing into the borehole. If this does not solve the problem then a densifier (weighting agent), normally barium sulfate, an inert product with a specific gravity of 4.1, is added to the drill mud mix in the pit. The densifier is mixed at quantities to cause the pressure head in the borehole to become greater than the pore pressures in the *in situ* soils thereby stopping the flow of the unconsolidated sands into the borehole annulus. It is important to note that we use no other chemical additives in the drilling mud mixes utilized for geotechnical activities. In addition, Shell would purchase and take on one lot of drilling additives at the start of the season and store in bulk tanks (or occasionally bagged pallet products, depending on availability) onboard the vessel for use the entire open-water season. Due to logistics, we never plan for drilling fluid additives resupply during actual field activities.

There are examples of geotechnical boreholes being drilled on the North Slope of Alaska to 150 feet (ft) without the use of drill mud additives. Shell expects to start each borehole with seawater as the drilling fluid, but may encounter situations in any boring where the additives identified above are necessary. When the encountered stratigraphy at any given boring site dictates the practical necessity of drilling fluid additives, we prepare for and use the drill mud gelling and weighting agents described above as needed to prevent lost or damaged equipment, or stuck drill pipe. Shell believes most boreholes to 50-ft can be conducted using only seawater unless an unconsolidated sand stratum is encountered shallow. For the deeper boreholes down to 499-ft depth we anticipate using drilling additives starting somewhere between 50- and 150-ft depth. Below 150-ft drilling additives will be necessary regardless if unconsolidated sands are encountered or not due to the need for drill string lubrication requirements at these depths.

Newer Seabed-Based Geotechnical Techniques. Since the early 2000s newer technologies have been developed in the marketplace that can be used to accomplish geotechnical activities offshore in the Alaskan Beaufort and Chukchi Seas. Most of these technologies have incorporated existing conventional slim-hole sampling techniques, *in situ* CPT testing methods, hardrock coring technologies, and remotely operated vehicle (ROV) telemetry to remotely operate the drill from the seabed. The methods utilized for advancing the borehole, sampling, and *in situ* testing are similar to those described under conventional technology; however there are some distinct advantages to the newer technology. The three main distinguishing features of the newer seabed-based technology and methodologies are; (1) the sampling unit is lowered to the seabed on an umbilical and operated remotely using ROV technology and telemetry.; 2) the overall borehole diameter is limited to a little over 4-inches utilizing slim-hole sampling and hard rock coring techniques; and, (3) the borehole is cased the entire depth so normally no drill

mud additives are required to advance the borehole. However, in extreme geologic conditions a viscosifier (gelling agent) may be needed to ease friction on the drill string.

These three features lead to several advantages for this technology. First, from a health and safety standpoint the newer technology significantly lowers risk and exposure for personnel as compared to conventional sampling that typically take place on the deck of the vessel by being remotely operated by ROV technology through the deployment umbilical. Secondly, the sediment cuttings generated by the newer technology are less than those generated by conventional techniques. For a typical 50-ft deep sampling borehole, only about 12 gallons of cuttings are generated as compared to about three or more barrels of cuttings for a conventionally advanced borehole using wet-rotary techniques (about 90% less). And finally, no drilling fluid additives are required other than the very seldom used viscosifier to aid in advancing the borehole in extreme geologic conditions.

There are drawbacks to the use of the newer seabed-based technology that preclude its use at this time for all but potentially the shallowest planned boreholes in the Arctic. The primary disadvantage is the fact that to date, most of the newer technology sampling units have not been proved out in similar geologic conditions as we may encounter in the Chukchi Sea. The second most important disadvantage is the fact that none of the newer sampling units currently available on the open market are able to store enough casing onboard to complete the deeper boreholes to total depth that we require for engineering design. Most of the newer sampling units are able to accommodate about 30 to 40 meters of casing in their twin carousels along with all the other sampling tools and drill pipes. Even Fugro's SeaFloor Drill (SFD), which can be loaded with over 60 meters of casing, cannot complete our planned 100 m+ boreholes without advancing and sampling beyond the total casing depth. Shell continues to track and evaluate this new technology and welcomes advances in the technology that may allow its use for our Arctic prospects.

Nearshore Geotechnical Technologies

There are a few proven technological options available to complete nearshore geotechnical surveys. Both conventional open-hole wet-rotary (as discussed in previous paragraphs) and cased-hole technologies may be employed to complete the shallow water boreholes. And cased-hole operations can be completed by conventional land-based methods using either standard N-Rod and Hollow Stem Auger sampling techniques. The nearshore geotechnical activities will be performed during the open-water season, concurrent with the offshore activities, or possibly in alternating years.

The biggest difference between offshore (>25 meters water depth) and nearshore (>5 meters to about <25 meters water depth) geotechnical surveys is the vessel requirements. Whereas a typical vessel which rises and falls with the seas is used to complete boreholes in water depths greater than 25 meters, a stable platform is required in shallower waters. A bottom-founded barge, more commonly called a liftboat, is typically utilized to perform geotechnical surveys in shallow water. This is due to the limited depth of water below the vessel's hull through which the unsupported drill string passes. The greater length of drill string between the vessel's hull and seabed in deeper waters is more flexible and forgiving in rough seas and high winds that tend to move the vessel around while stationed on location with DP. Also, nearly all of the dedicated DP-class geotechnical vessels available are rather large at 75 meters to over 100 meters in length. These large vessels draw significant draught at about 5 to 7 meters. Most if not all of these vessels experience great difficulty attempting to hold position on DP in these shallow waters. The use of a liftboat to perform the shallow water geotechnical surveys eliminates the

limitations of larger DP vessels working in shallow water depths with possible rough sea conditions.

There are competent contractors located in Alaska that can perform the nearshore geotechnical surveys from a liftboat utilizing land-based, cased-hole technology with either N-Rod or Hollow Stem Auger techniques. Numerous advantages can be realized by performing the nearshore work with either of these methods over conventional offshore open-hole wet-rotary techniques. If site conditions allow for cased-hole techniques, the holes can be advanced through casing that is driven into a competent stratum in the substrate that can provide a competent seal at the shoe of the casing. When performing geotechnical surveys through a string of casing in the water column, the drilling fluid, which may or may not be only seawater if conditions dictate, and cuttings returns are taken at the liftboat deck and recirculated to further advance the borehole until the mud will no longer shear and lift the cuttings out of the borehole. At this point, the drilling fluid may be refreshed with additional gelling additive and weight material. The formation cuttings are screened off and stored in barrels or a dedicated liquid storage tank for later disposal on land in an approved facility. In this way, very little drill mud is consumed over the course of the entire project as compared to that used offshore. In addition, as indicated by the above statement, no drill mud or cuttings are discharged into the environment at the seabed as in offshore wet-rotary techniques. Occasionally a leak will develop at the shoe of the casing string and allow a little drilling fluid to seep into the environment at the mudline. Normally the casing string is merely driven (or drilled) a little deeper into the substrate to reseal the casing shoe. If site conditions allow the use of cased-hole techniques then there is the possibility for further reduction of trace drilling mud or formation cuttings being discharged, and even a lesser chance of perceived impact to subsistence activities in the nearshore.

Shore-Crossing (Transition Zone) and Onshore Geotechnical Technologies and Timing

Like the nearshore geotechnical surveys discussed above, the shore crossing, or transition zone to onshore geotechnical surveys both use land-based, cased-hole technology utilizing either N-Rod or Hollow Stem Auger techniques. Instead of a vessel, the rig, core sampling and *in situ* PCPT sounding tools are mounted on Rolligons along with all the other support equipment including living quarters, galley, spare parts and shop, cooled and frozen sample storage, bulk drilling mud additives storage, and mud and cuttings disposal tanks. In the past Shell preferred to do shore-crossing, transition zone and onshore geotechnical surveys starting in March of any given year when the snow pack and landfast ice were the thickest. As Shell already presented in the "Timing of Activities" response to EPA's Question #4, Shell has successfully completed shore-crossing (transition zone) geotechnical surveys from landfast ice in Camden Bay in 2006 but is willing to plan to perform this work starting in January in future years. Assuming landfast ice thicknesses are sufficient, through performing surveys in January we will be out of the area prior to the start of the spring bowhead whale subsistence harvests. As with nearshore geotechnical surveys, if site conditions allow the use of cased-hole techniques, then there is the possibility of further reduction of discharge of trace drilling mud or formation cuttings.